Latest Perspectives on the RIA Facility Design at MSU

R.C. York

August 2003

General Comments

- RIA facility design has been developed over a number of years by a number of groups
- Technical Risks
  - No "Show Stoppers" but significant challenges
- Significant efforts on the driver linac
  - Optimization strategies & detailed considerations
- Relatively less activity on the target and experimental areas
  - Recently these arenas have seen dramatic increase in focus
  - Significant challenges and issues recognized

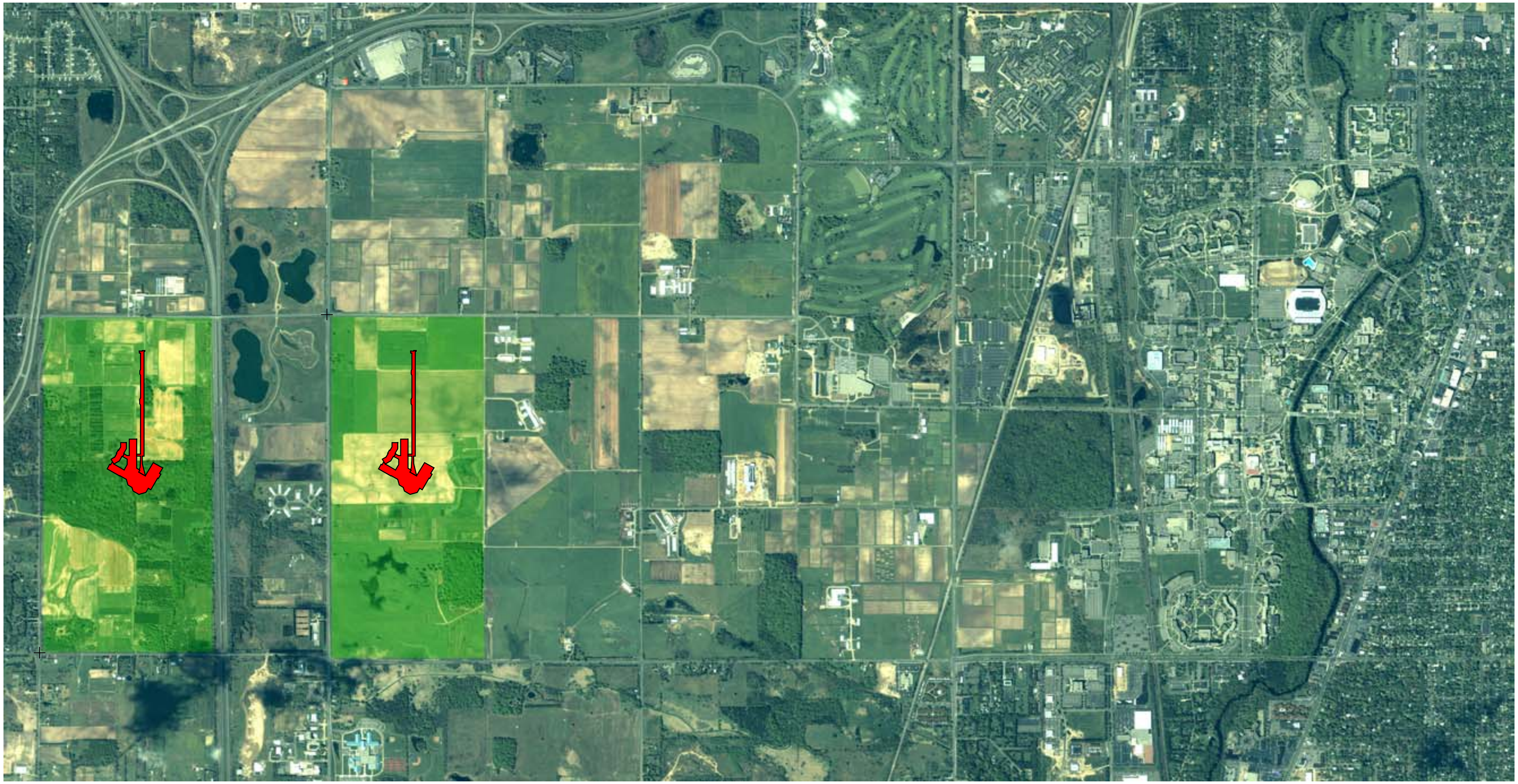
MSU Design Approach

- Site will have appropriate space
  - Layout optimization unconstrained by space
  - Large range of possibilities for future capabilities
- Design evaluations
  - Minimize risks to schedule & performance
  - Enhance facility potential for implementation of improvements without significant interruptions for users

RIA at MSU

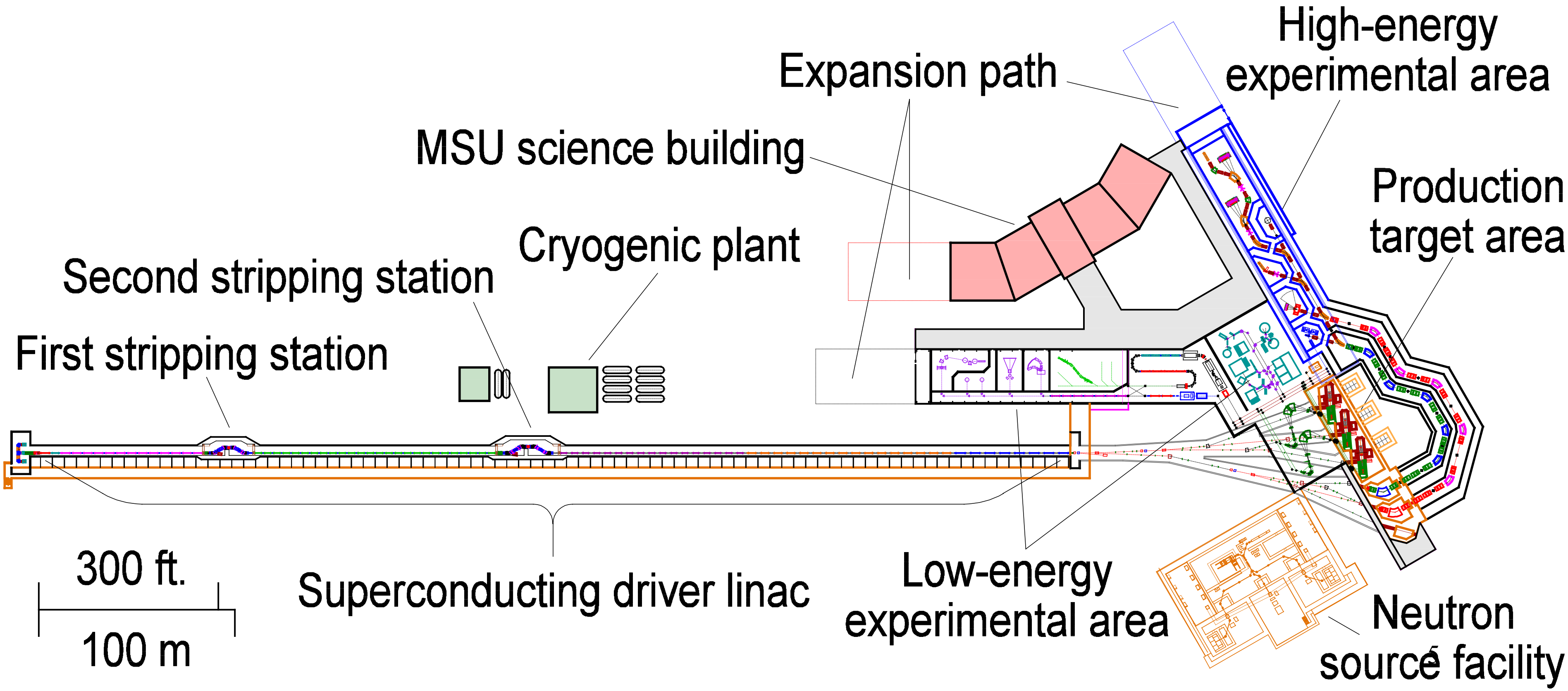
- Over 5000 acre campus – several potential sites within 5 minutes of classroom
- Next generation scientists & multi-discipline synergies

→ North



MSU RIA Layout

- **Driver linac straight (shown) or folded – decision based on optimization**
- **Future expansion paths for experimental areas**



Driver Linac Common Concepts

- **Multiple charge state acceleration (>Xe)**
- **Two stripping stations (>Xe)**
- **Room temperature technology through RFQ**
- **Superconducting technology beyond RFQ**
- **Superconducting solenoid focusing in first two linac segments**

Driver Linac Concept Variations

- 10th sub-harmonic (80.5 MHz) accelerating lattice
  - **Reduction in microphonics – avoid VCX tuners**
    - Mechanical damper & modest rf (Legnaro)
  - **6D acceptance found similar to 14th sub-harmonic (57.5 MHz)**
- Only 6 cavity types – prototyped by end of 2003
  - **Advantage taken of Legnaro & SNS experience**
  - **Supports early infrastructure definition**
- Details reported at RIA Driver Linac Workshop (May 2002)

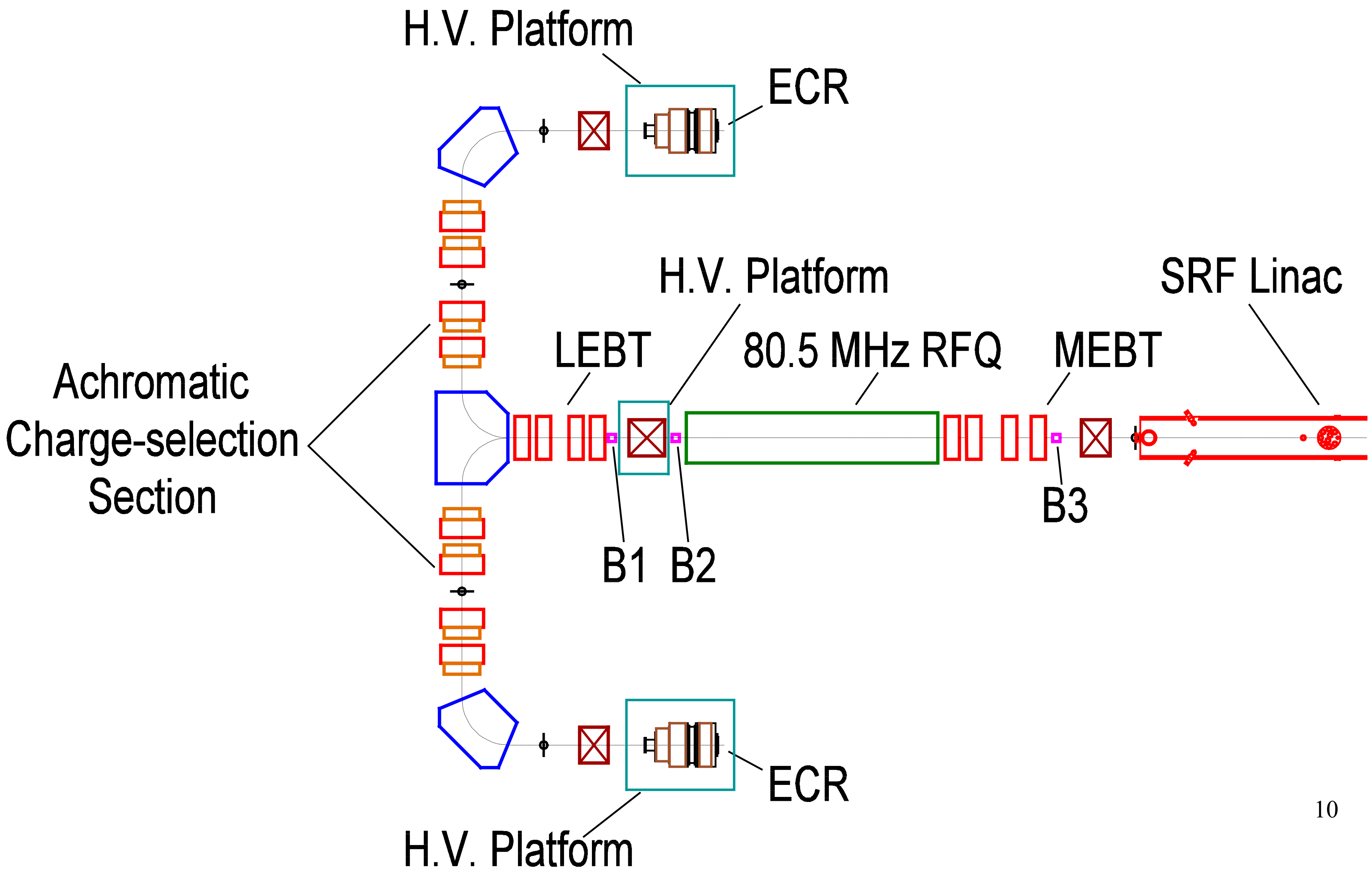
Driver Linac General

- **Design driven by 400 MeV/nucleon uranium**
- **28+ & 29+ U injected into SC linac at 292 keV/u**
- ***Segment I***
  - **Accelerated to ~12 MeV/u & stripped**
- ***Segment II***
  - **5 charge states (73±2) accelerated to ~90 MeV/u**
- ***Segment III***
  - **Stripped and 3 charge states (88 ±1) accelerated to 400 MeV/u**

Driver Linac Sample Beam List

Ion	A	Z	Segment I Energy (MeV/u)	Segment II Energy (MeV/u)	Segment III Energy (MeV/u)
H	1	1	11.8	239	1019
^{3}He	3	2	11.8	172	777
D	2	1	11.8	136	622
O	18	8	11.8	123	560
Ar	40	18	11.8	124	566
Kr	86	36	11.8	109	510
Xe	136	54	11.8	101	470
U	**238**	**92**	**11.8**	**89**	**400**

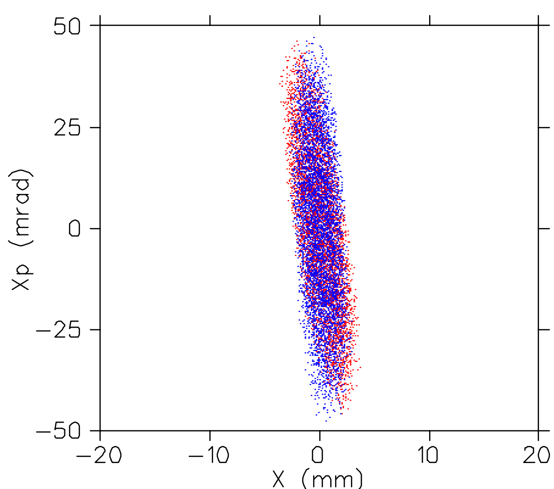
Driver Linac Front End

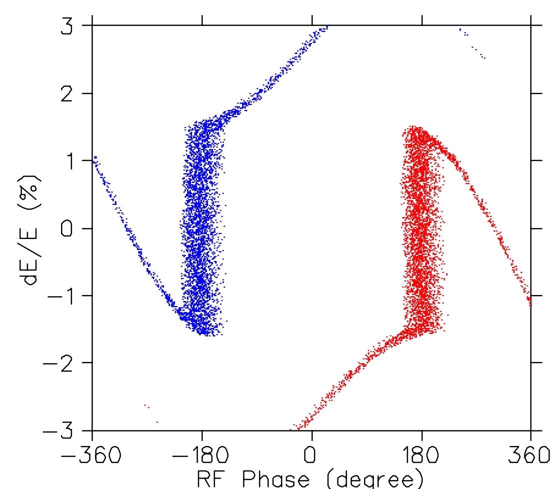


Low Energy Beam Transport (LEBT)

- **Beam pre-bunched for RFQ**
- **Additional buncher system to put two-charge-state beams (>Xe) in every other RFQ bucket**
  - **Similar to ANL design**

Ion	**A**	**Q**	**Vp (kV)**	**Buncher Voltage (kV)**	
				B1 (1st harmonic)	**B2**
Xe	136	19 & 20	-52.38	1.242	1.754
Au	197	23 & 24	0	2.134	2.135
U	238	28 & 29	+38.95	2.728	2.141





29+

28+

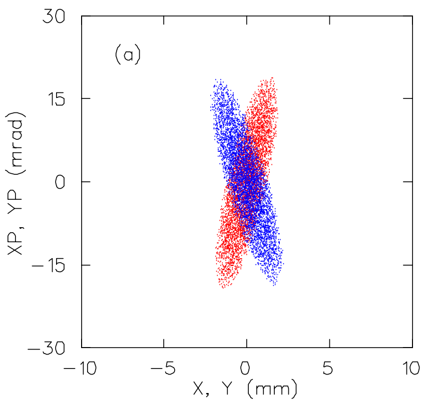
RFQ

- **Frequency 80.5 MHz – 10th sub-harmonic of 805 MHz**
- **Input energy = 12 keV/u**
- **Output energy = 292 keV/u**
- **Transverse dynamics similar for two charge states**
- **Ratio longitudinal emittance / linac acceptance**
  - **Ratio within ~10% of 14th sub-harmonic case** ☑

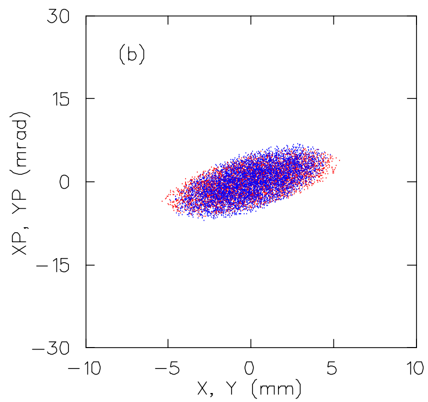
Parameter	**Value**
Length	3.07 m
Mean radius R_0	6.5 mm
Transverse electrode curvature ρ	$0.8 \times R_0$
Minimum aperture a	6.19 → 4.44 mm
Modulation factor m	1.1 → 1.92
Synchronous phase Φ_s	-25 ° → -20 °
Voltage	90 kV
Number of cells	123

Medium Energy Beam Transport (MEBT)

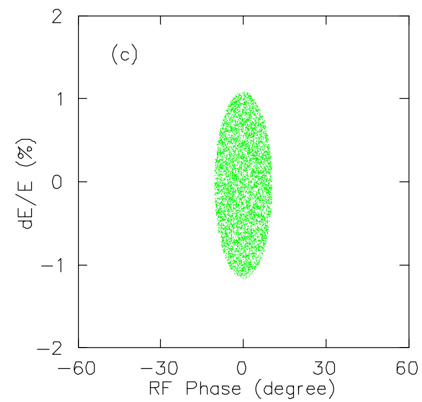
- **6D match of RFQ beam to superconducting linac**
- **PARMELA simulations**



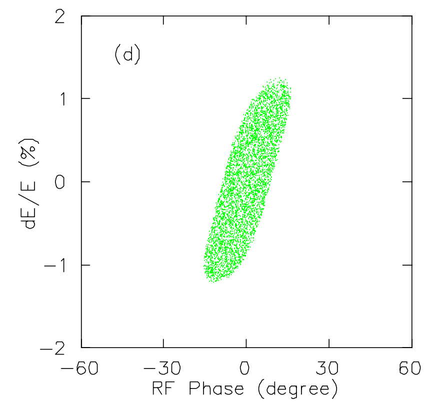
RFQ exit transverse



MEBT exit transverse



RFQ exit Longitudinal



MEBT exit Longitudinal

NSCL

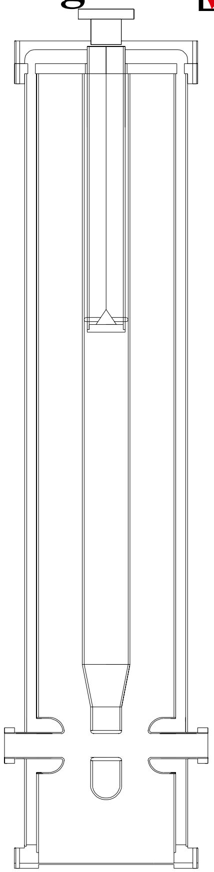
Superconducting Segments

- **6 cavity types**
  - ***If* reduce to 5 cavity types by removing β_{opt} =0.83**
    - Fewer spares & NRE benefits
    - Result is proton energies of ~740 MeV

Cavity Type	βopt	f (MHz)	Peak E field (MV/m)	T (K)	Linac Segment	# Of Cryostats
λ/4	0.041	80.5	16.5	4.2	I	2
λ/4	0.085	80.5	20	4.2	I	13
λ/2	0.285	322	25	2	II	26
Ellip.	0.49	805	32.5	2	III	17
Ellip.	0.63	805	32.5	2	III	16
Ellip.	0.83	805	32.5	2	III	8

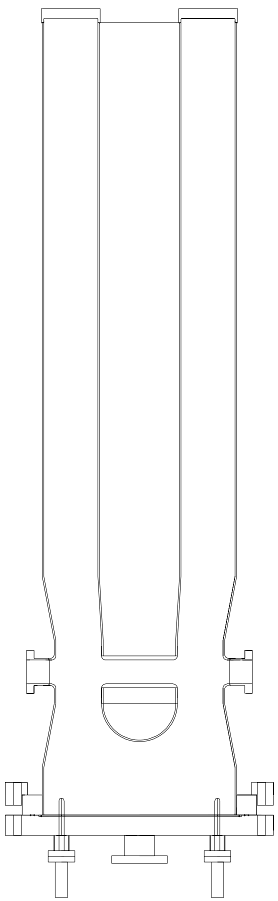
Superconducting Structures - [1]

Legnaro



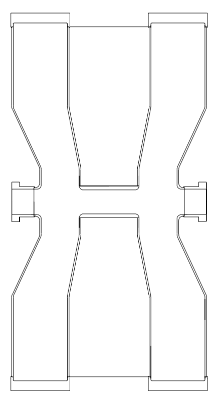
$\beta_{opt}=0.041$
80.5 MHz

MSU

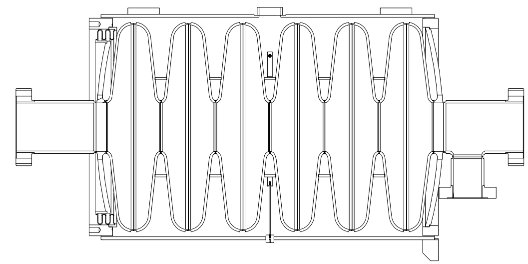


$\beta_{opt}=0.085$
80.5 MHz

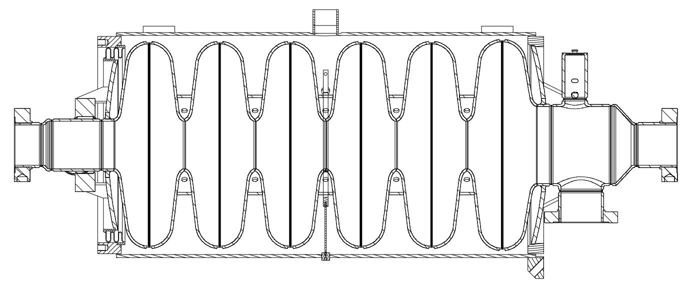
MSU



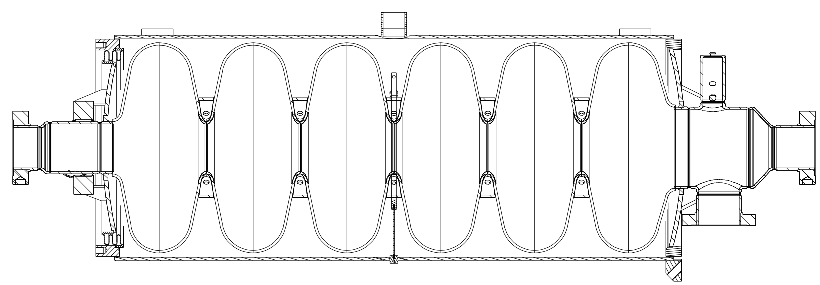
$\beta_{opt}=0.285$
322 MHz



$\beta_{opt}=0.49$
805 MHz
MSU/JLAB



$\beta_{opt}=0.63$
805 MHz
SNS



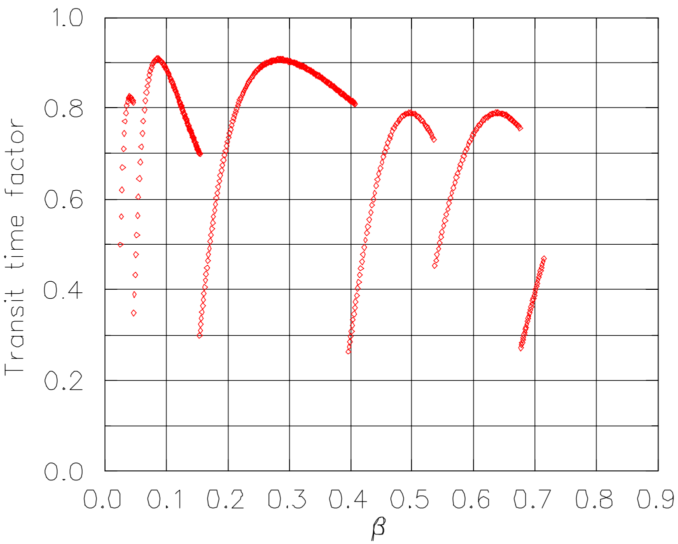
$\beta_{opt}=0.83$
805 MHz
SNS

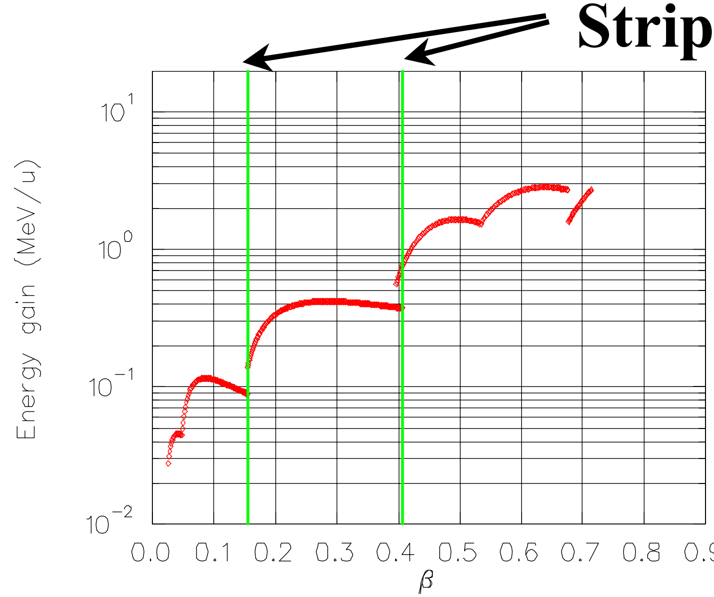
Superconducting Structures - [2]

- *See details in Terry Grimm's Talks (Wed.)*
- All cavity types tested by end of year
- 2 types of $\lambda/4$ cavities
  - ✓ (β=0.041, 80.5 MHz) – (similar to Legnaro)
  - (β=0.085, 80.5 MHz) – tested by end of year
- 1 type of $\lambda/2$ cavity
  - ✓ (β=0.285, 322 MHz) – demonstrated – exceeds specs
- 3 types of elliptical 6 – cells
  - ✓ (β=0.49, 805 MHz) – demonstrated – exceeds specs
  - ✓ (β=0.63, 805 MHz) – demonstrated – exceeds specs
  - ✓ (β=0.83, 805 MHz) – demonstrated – exceeds specs

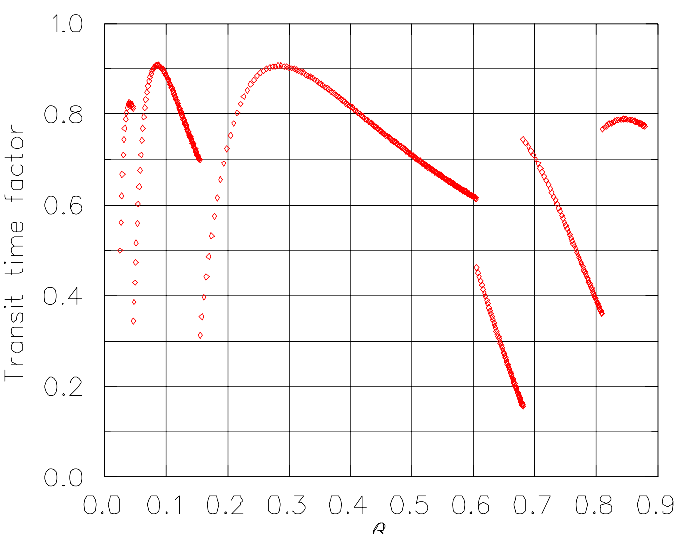
Transit Time Factors & Energy Gain

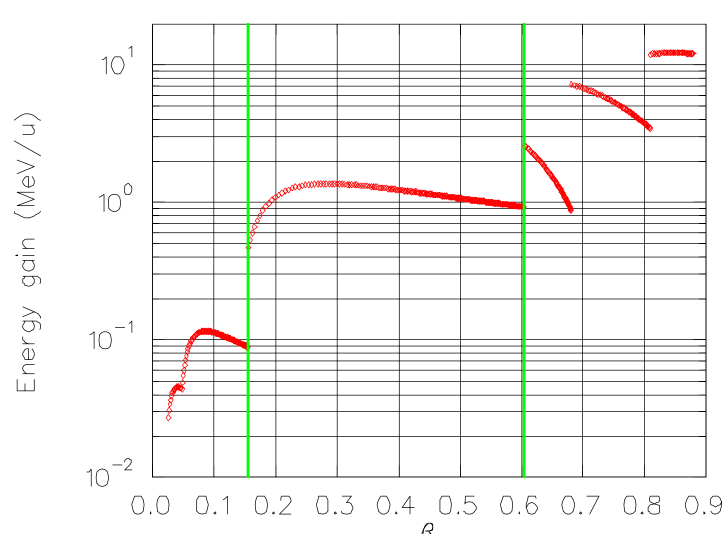
Stripping locations





U

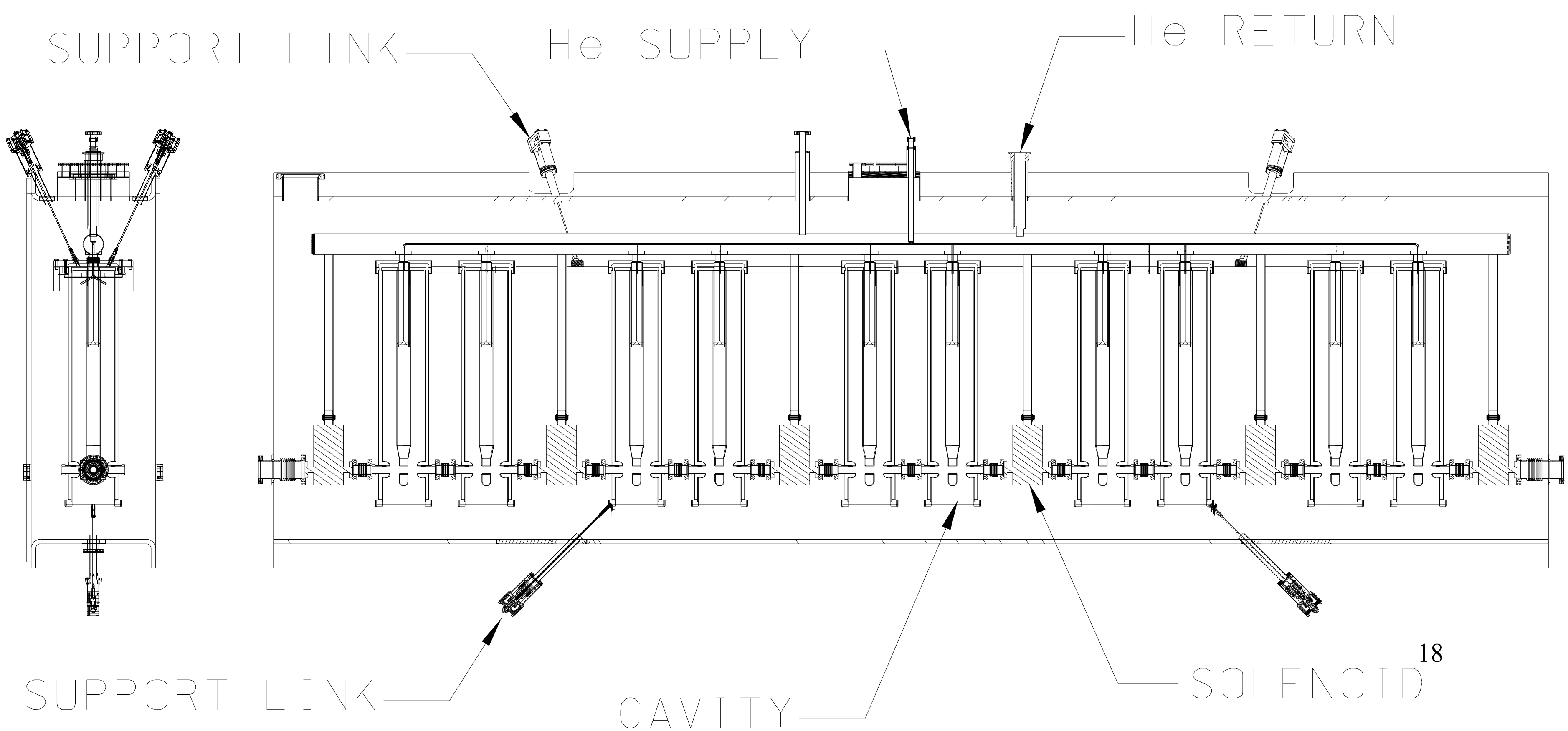




H

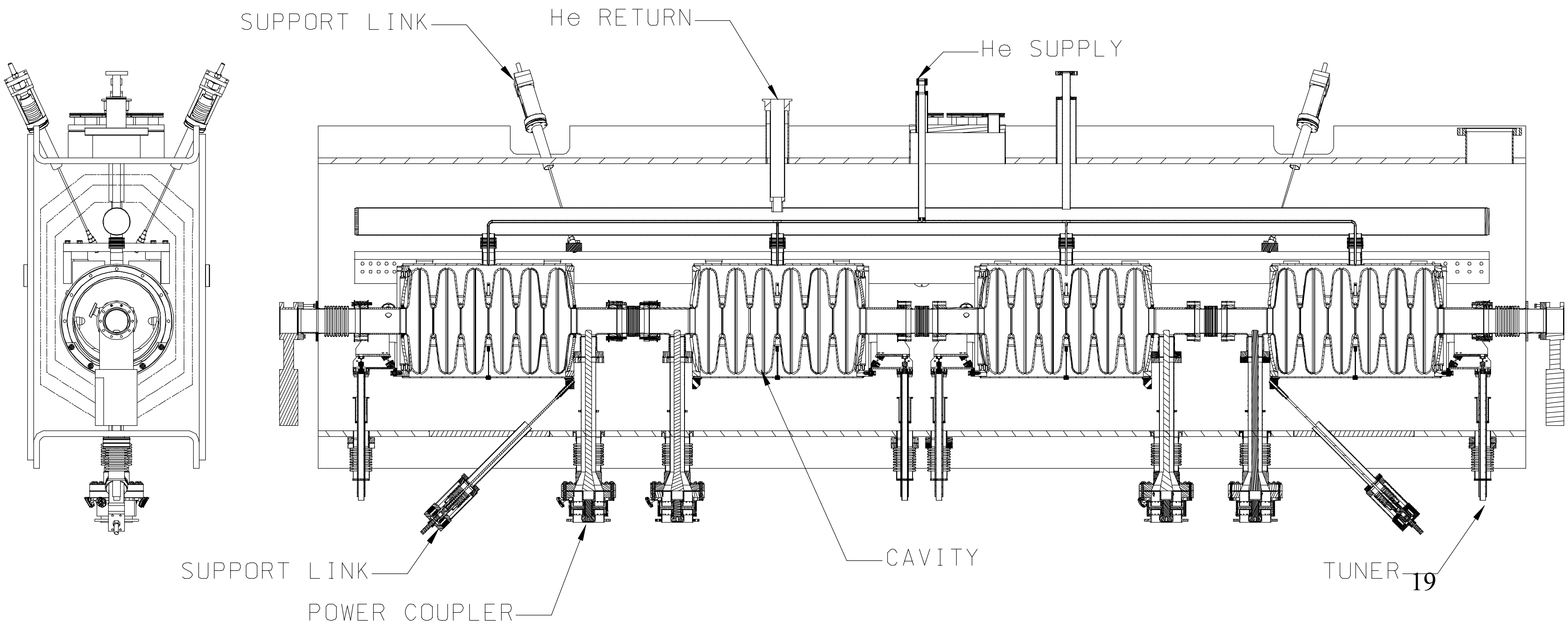
Segments I & II Cryostats

- **Isolated vacuum**
- **Superconducting solenoid focusing**



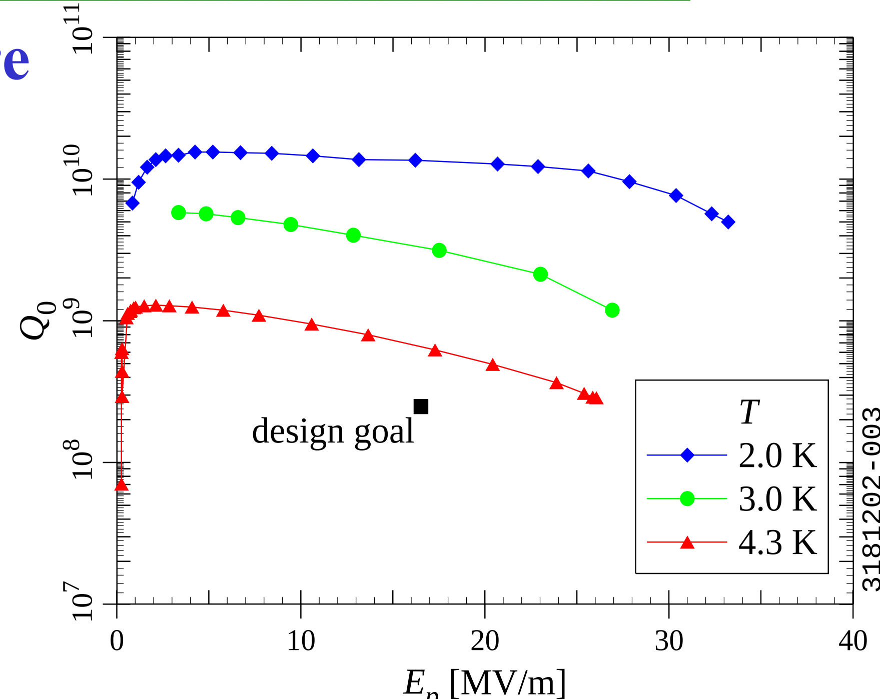
Segment III Cryostats

- **Isolated Vacuum**
- **Two-cavity prototype – complete in ’03, tested in ‘04**



Cryogenic Plant Optimization

- **Q vs. Ep as function of temperature**
- **Operate λ/2 at 2 K**
  - **~10% less wall plug power**
  - **~17% less capital cost**

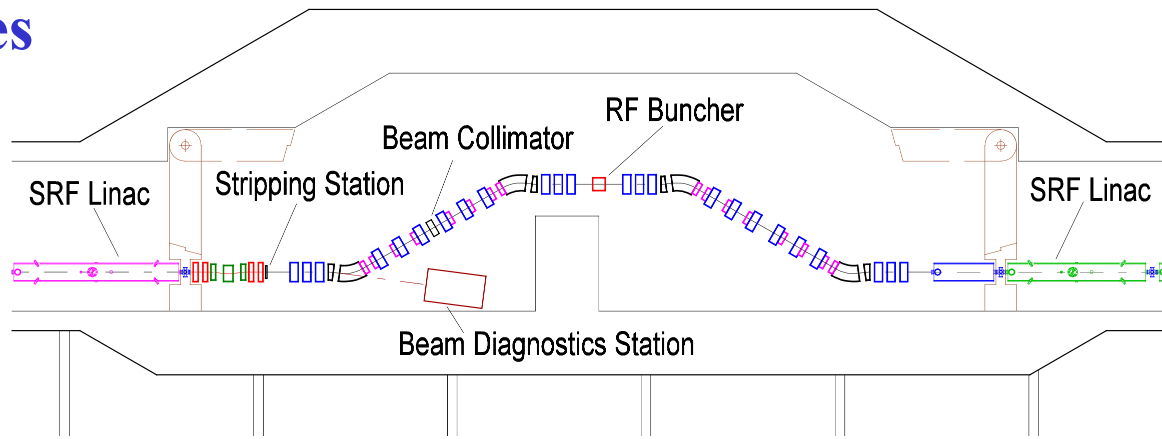


Cavity Operating Temperatures (K)			Cryogenic Plant			
λ/4	λ/2	Segment 3	4.2 K Capacity (kW)	2 K Capacity (kW)	Wall Plug (MW)	Capital Cost (M$)
4.2	4.2	2 ellipticals	16.3	13.4	14.9	41
4.2	2	2 ellipticals	2.7	15.2	13.2	34

Driver Linac Stripping Chicanes

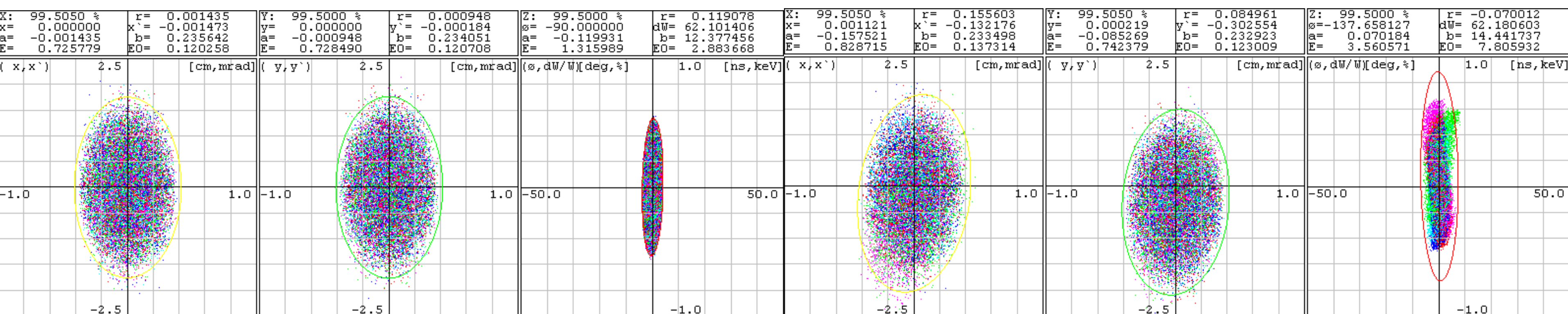
- **High symmetry – good higher-order corrections**
- **Positioned to support longitudinal matching at frequency changes**

1[st] Stripping Chicane



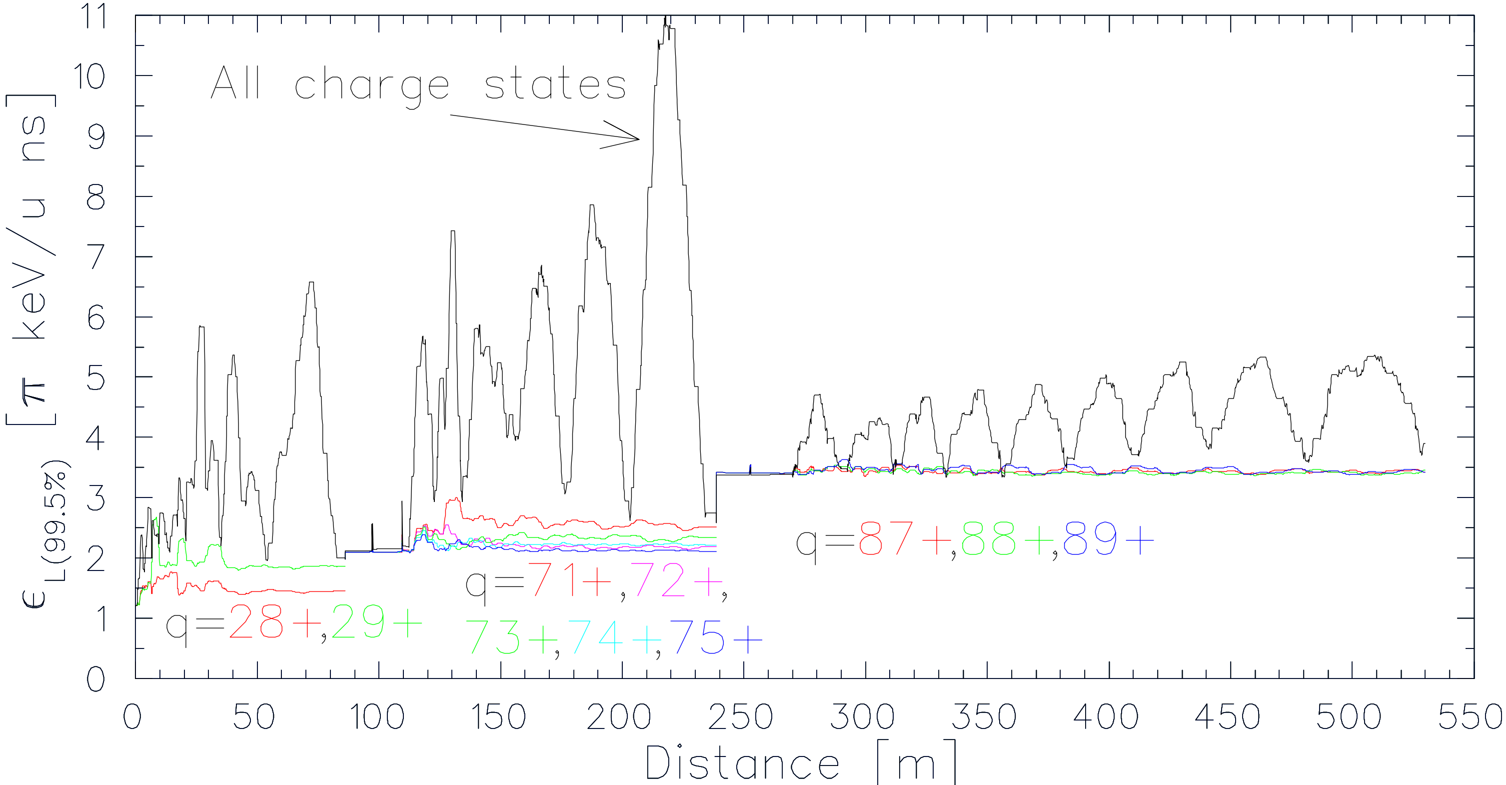
Entrance | Exit

X | Y | Z | X | Y | Z



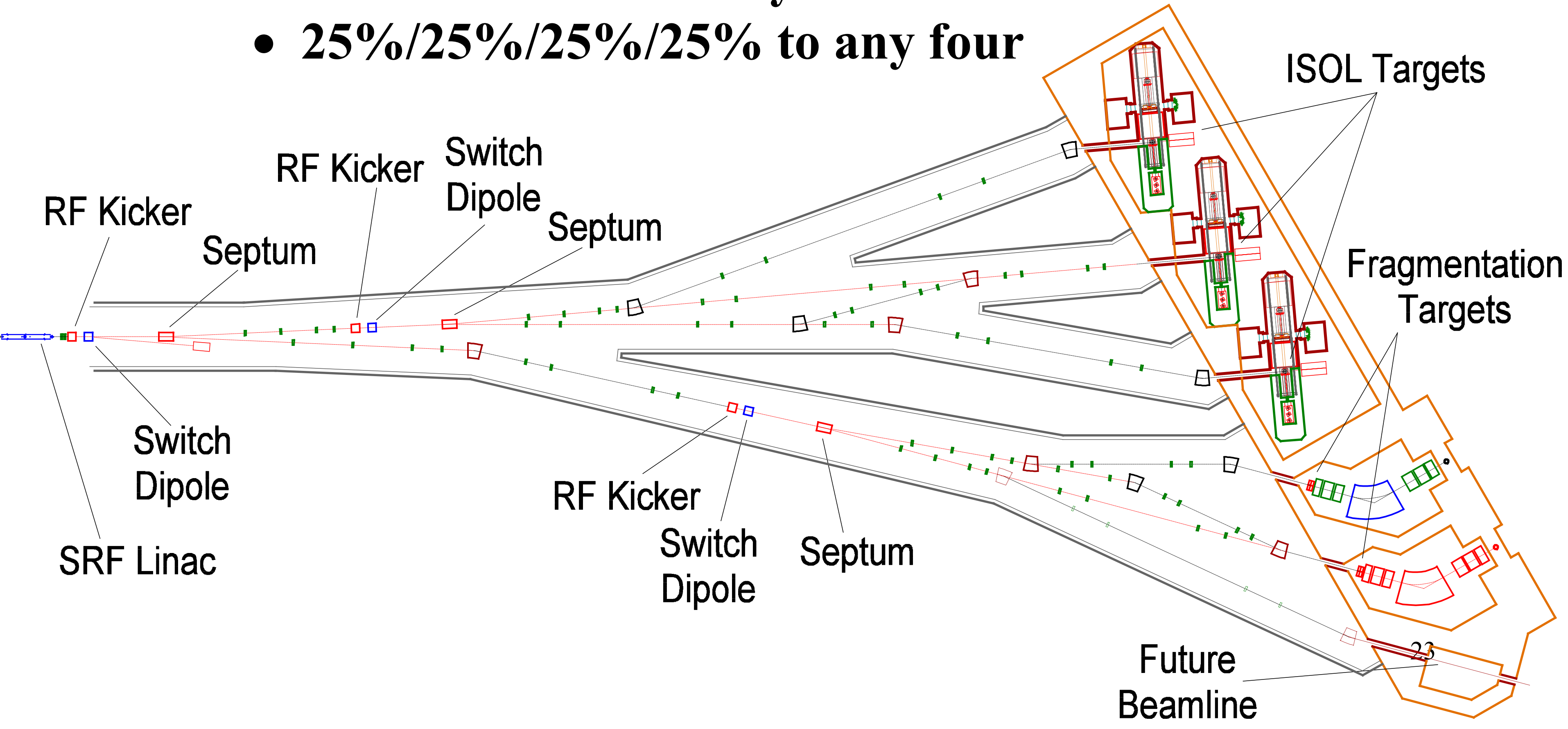
Driver Linac Dynamics

- **6D dynamic evaluations – no problems & reasonable tolerances –** ***See Wednesday talk by Wu***
  - **SRF cavities – $\sigma_{x,y}$ = 1 mm, V= 0.5%, ϕ=0.5^o**
  - **Solenoids - $\sigma_{x,y}$ = 0.25 & 0.5 mm (Seg. I & II)**
  - **Quads - $\sigma_{x,y}$ = 1 mm, σ_z= 5 mrad (Seg. III)**



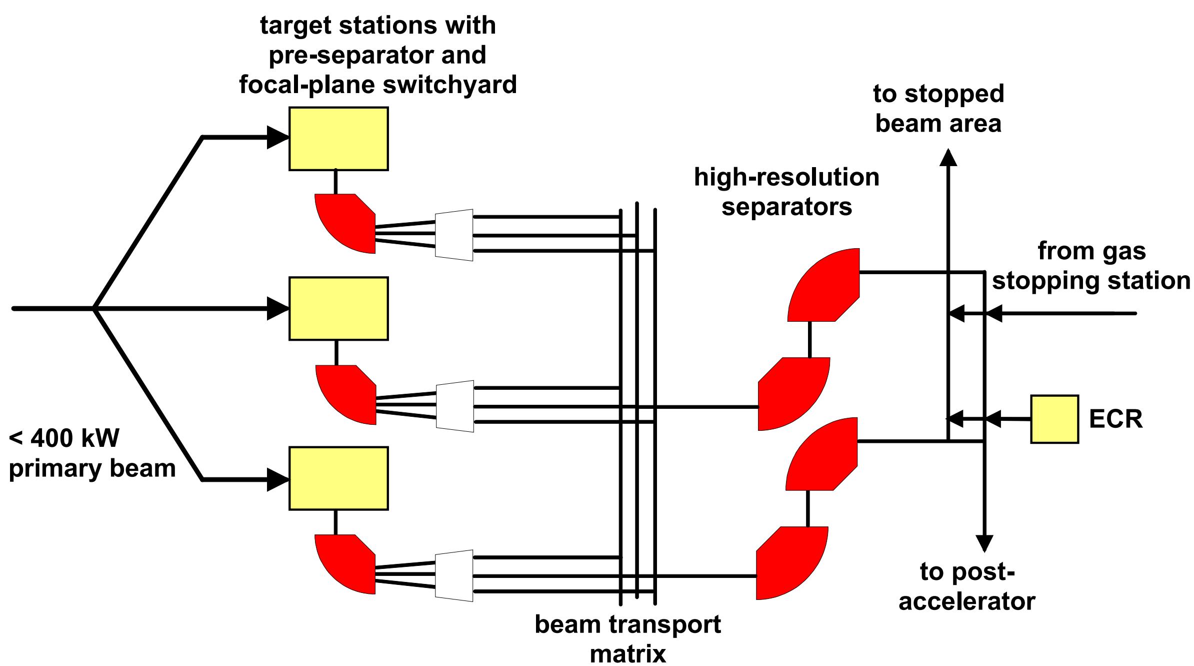
Driver Linac Switch Yard

- **Revised to accommodate target area developments & to increase flexibility**
  - **100% to any one, 50%/50% to any two**
  - **50%/25%/25% to any three**
  - **25%/25%/25%/25% to any four**



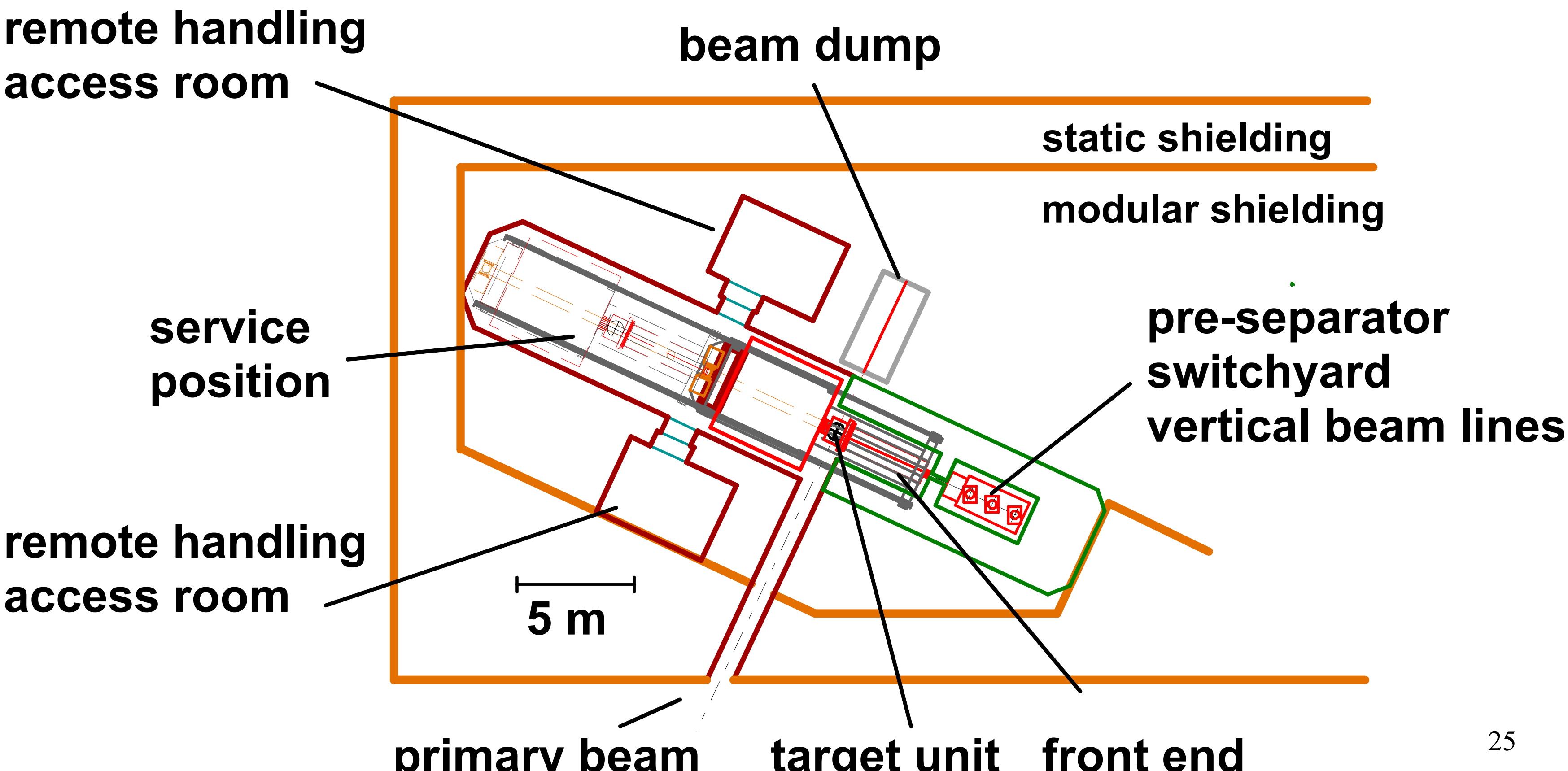
ISOL Target Area Concepts

- *See Bollen talks on Wednesday*
- 400 kW beam power – *Many R&D Issues*
  - ~10x existing designs - *major technical challenge for ISOL targets*
  - Infrastructure proposed suitable for ultimate 400 kW
- Three (possibly staged) ISOL target stations proposed
  - Redundancy & beam development & R&D to higher powers
- Goal to maximize usability of ISOL beams produced in any station



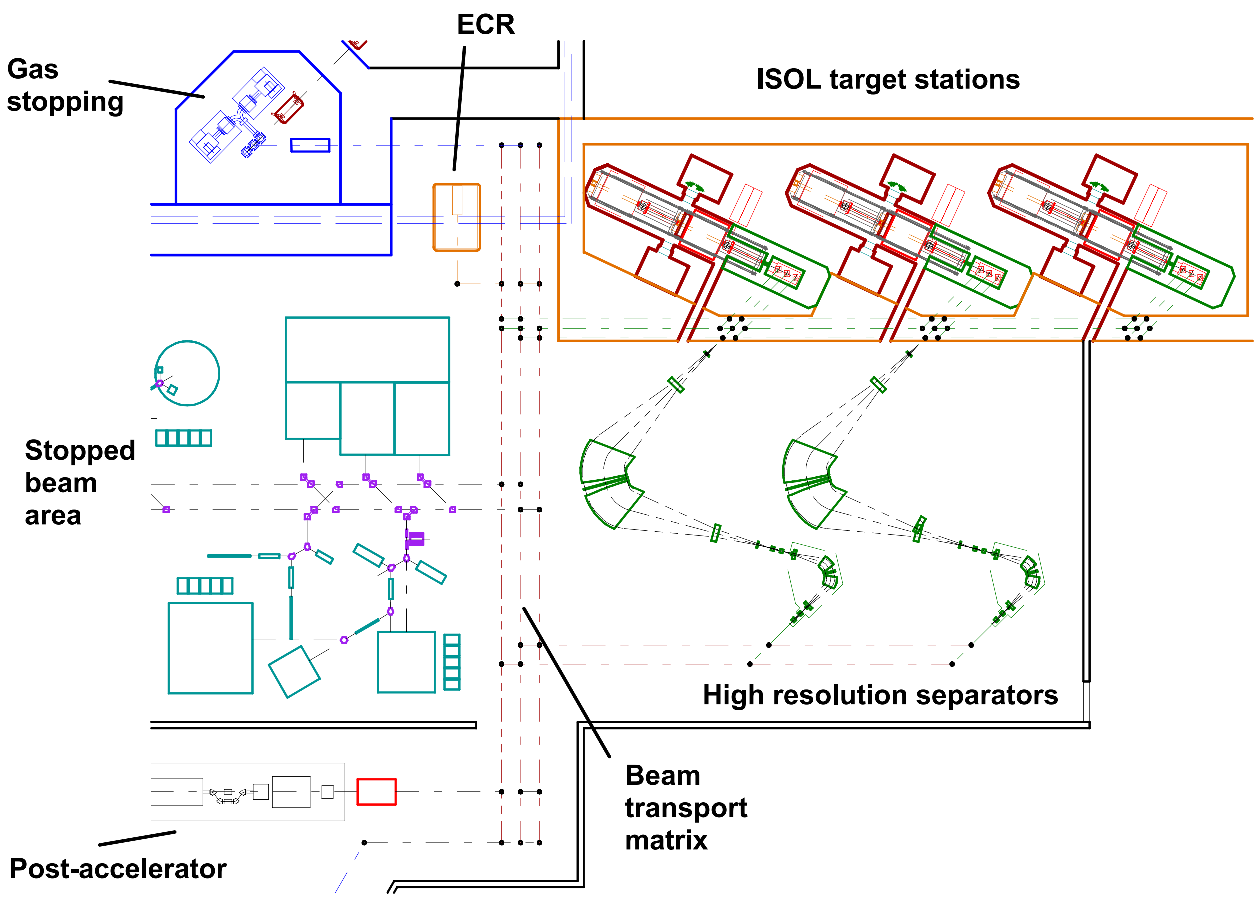
ISOL Target Station

- **400 kW infrastructure & shielding so access to other stations possible when beam delivered to others – *R&D Required***



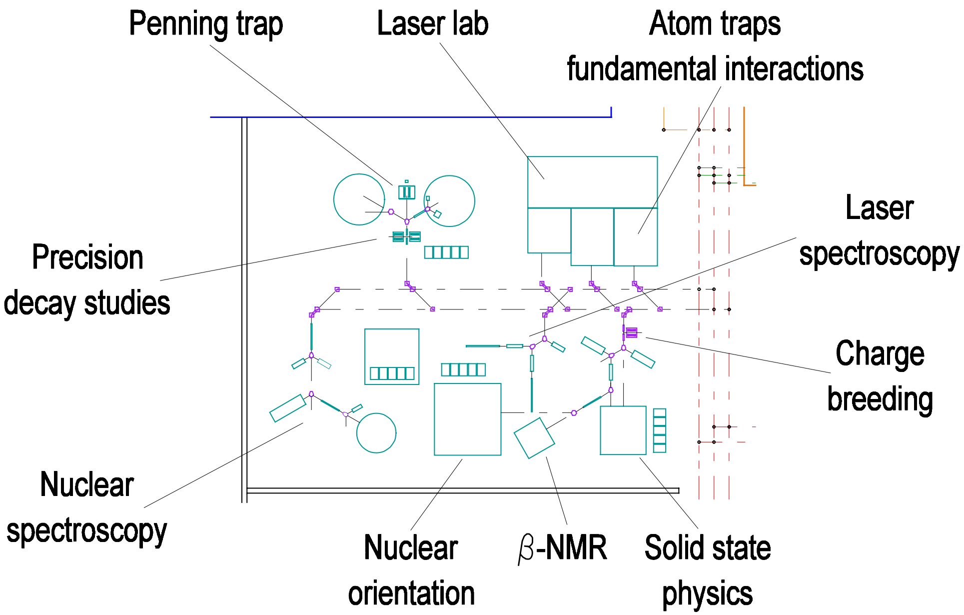
Layout of ISOL Area

- **Important to make design compatible with very different types of targets**
- **Mass separators with beam cooling may be better & cheaper – *R&D Required***
- **Post accelerator (8 MeV/u for A up to 240, 20 MeV/u for A<60)**

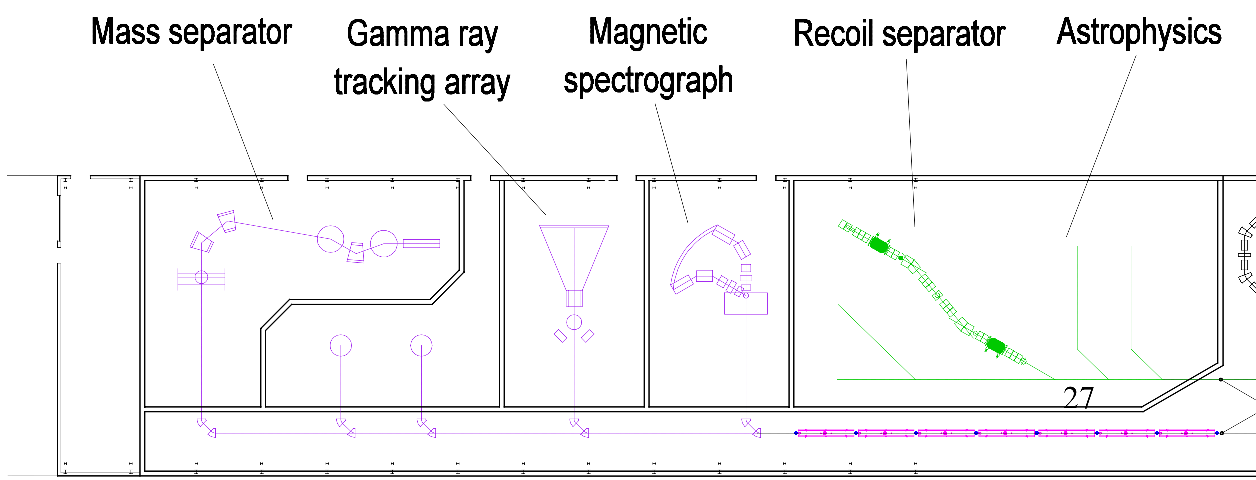


Low-energy & Stopped Beam Experimental Area

- Compatible with ORNL 2003 workshop



Stopped beam Area



Low-energy Area

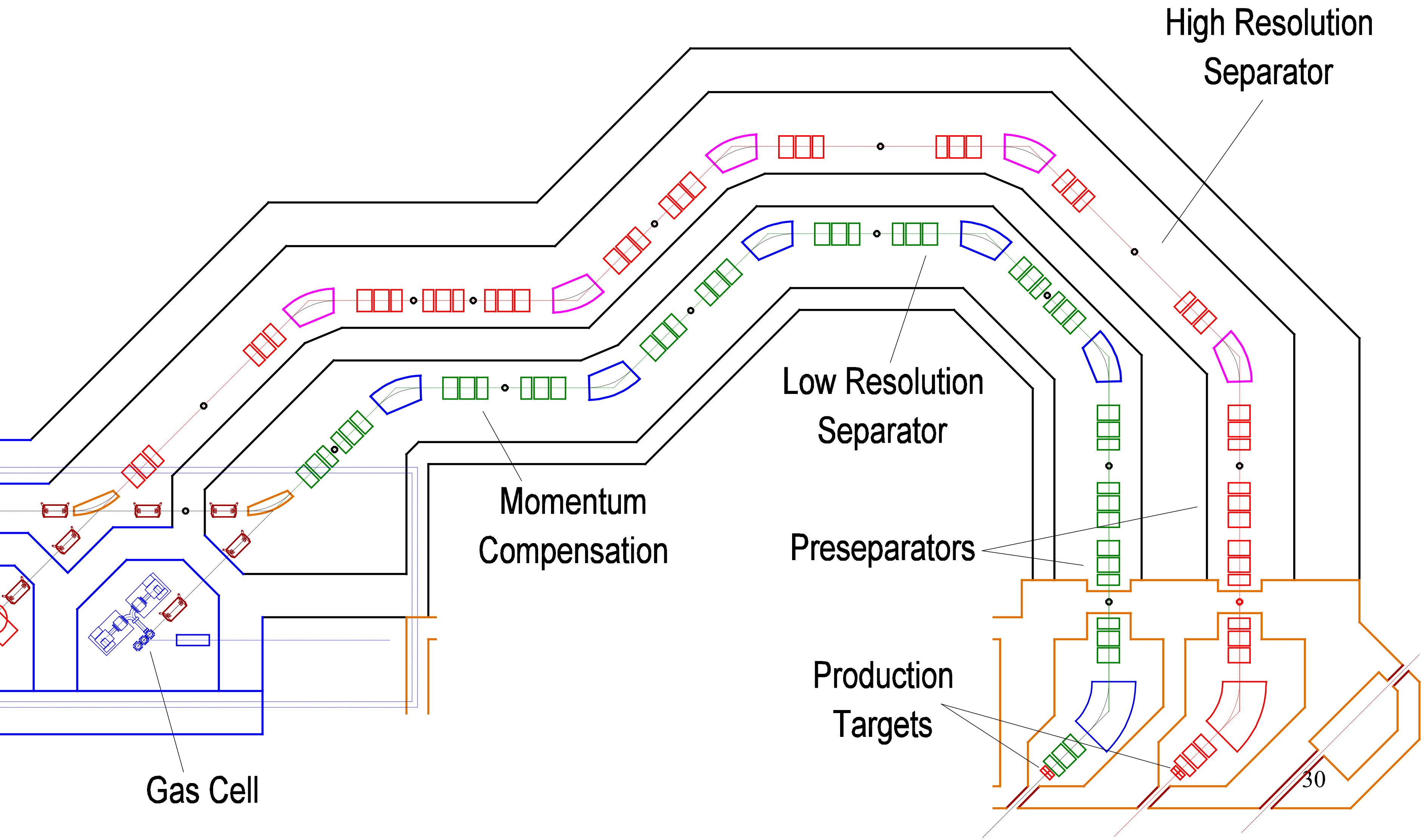
Fragmentation Area Concepts

- *See Wednesday Talks by:*
  - *Morrissey, Sherrill, Ronningen, & Zeller*
- Two fragmentation separation systems proposed
  - High acceptance to helium gas stopping station
  - High resolution to high energy area
  - Both could feed to high energy experimental area
- Third channel provided for primary beam to future possibilities

Fragmentation Production Area

- **Targets** – ***R&D challenge***
  - **High power density - ~ 500 kW/cm^3 (400 kW primary beam)**
    - Small spot size – reduce geometric aberrations
    - ~20% of beam power lost in target
- **Pre-separator concept**
  - **Begin to isolate downstream system from very high radiation environment**
- **High performance & radiation resistant magnets required – R&D challenge**
- **Characterization of radiation fields – required to support R&D efforts**

Fragmentation Separation Area Layout



Fragment Separators

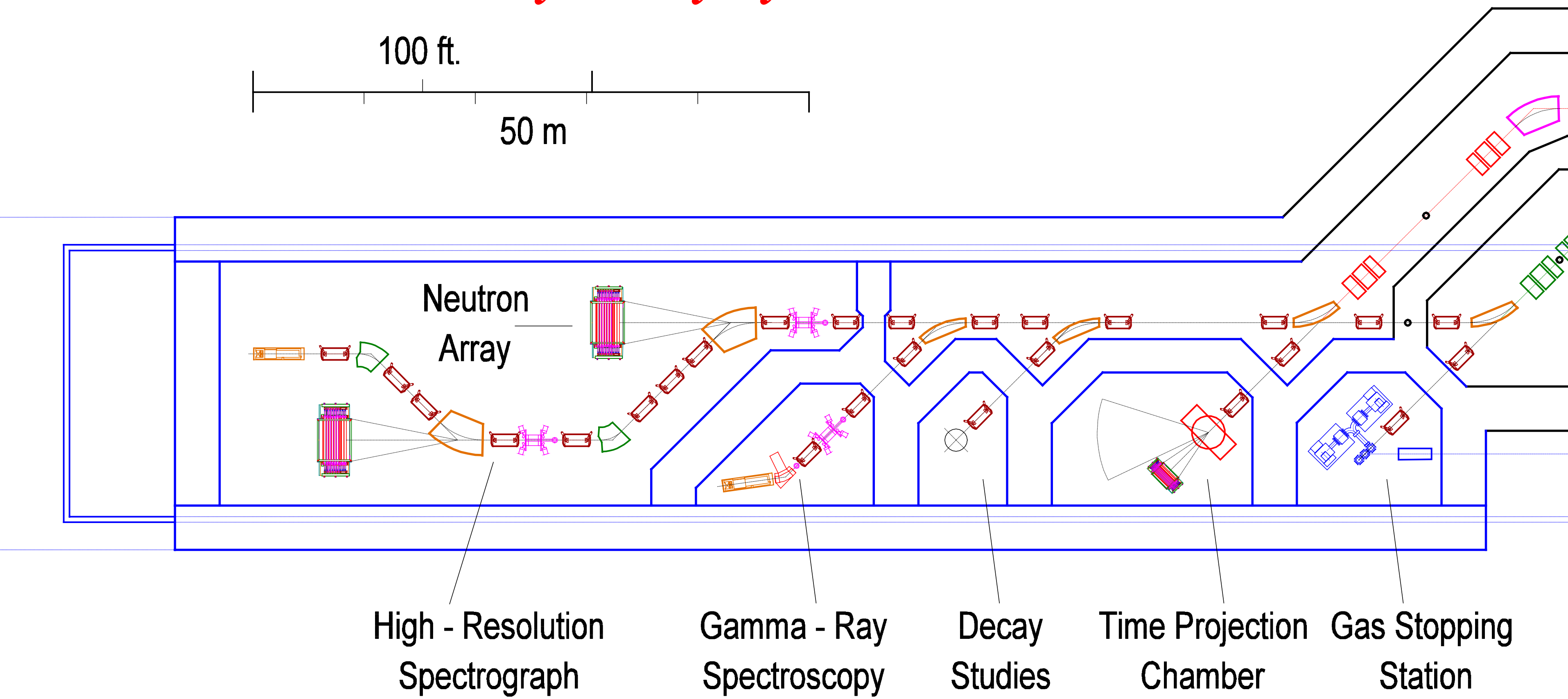
- High acceptance design feeding helium gas stopping station
  - 10 T-m, 12% momentum acceptance, 10 msr
- High resolution design feeding fast beam area
  - 10 T-m, 6% momentum acceptance, 8 msr
  - Similar to NSCL design
- Pre-separator segment
  - Remove primary beam & most of unwanted fragments
- *R&D Challenge*
  - Optical design with radiation resistant magnets and beam interception elements

Gas Stopping Station

- Layout
  - Provides beam from gas stopping to low-energy area
  - Allows use of fragment separator to send beam to high-energy area
- Good R&D progress made with NSCL gas cell
  - Shown ~50% incident ion implanted
  - Shown range-compression technique workable
- *Outstanding R&D questions remain*
  - What is system efficiency?
  - What is rate limitation?

High Energy Experimental Area

- *See Tuesday talk by Thoennessen*
- *See Wednesday talk by Lynch*



Summary

- **Fully general RIA facility accommodating baseline and future capabilities has been developed**
- **Driver linac with beam transport**
  - **Well detailed design**
  - **SRF R&D remains**
- **Target and experimental areas**
  - **General designs defined & issues identified**
  - **Provides for large range of possibilities for future capabilities**
  - **R&D priorities identified**